HEALTH TELEMATICS AND ITS SOCIETAL IMPLICATIONS

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Summary

Health telematics is one of the newest and most powerful of recent additions to the health care armamentarium. This article describes the basic characteristics of health telematics, and outlines some of the various sub-disciplines that find application in a powerful and widely applied new field of education and practice. Based on developments in communications, imaging, and information technologies, health telematics makes possible the near instantaneous provision of medical images and other health-related information over vast distances. Consequently, its impact on training, diagnoses, consultations, interventions, and emergency support promises to make up-to-date health care accessible in places and situations where none, or very little, has been available before. Of course, as in all human endeavors, there are both positive and negative aspects to any technology.

The many benefits of health telematics make it an area of rapid development in regional, national, and international health care initiatives. People can be diagnosed and treated at local clinics, without having to travel to distant hospitals. Health telematics can also reduce the isolation of chronically ill or handicapped persons. Health information and education can be made available in communities of hitherto disadvantaged and under-served populations. In addition, the possibility of home monitoring of chronically ill patients reduces admissions to, and lengths of stay in, hospital. Besides leading to direct improvements in public health services, including emergency medicine and triage in emergency situations, health telematics also, more indirectly, increases collegial support among medical personnel working in remote and isolated areas, making traditionally under-served areas more attractive to beginning professionals in medicine, education, and other areas.

However, the potential downsides of the technology are not negligible. Systematic and authoritarian abuse of health telematics (using *health* in the broadest possible sense) could seriously compromise the personal rights and freedoms of the world's peoples. The likelihood of governmental and commercial agencies (now and in the future) making less than benign use of information and communication technologies to collect, link, store, and search vast archives of personal information on citizens and consumers is extremely high—in fact, in some countries it is already happening. That some of these agencies have and/or will have the potential to become totalitarian is also hard to ignore. This potential is both amplified and attenuated by health telematics: *amplified* because it makes the harnessing of personal information for harm much easier; *attenuated* because for the first time in human history it is possible for people to communicate instantly and widely among themselves, at least those who have access to the requisite technology. What remains in doubt is the role that citizens, and especially health telematics professionals, will play as these technologies threaten to invade every aspect of our private and public lives. The big question now is whether or not health telematics will turn out to have had a net beneficial or a net dehumanizing impact on the human condition. Readers of this article might do well to ask themselves how they think this question will be answered over the coming years, keeping in mind its closing statement: *May all our actions be mindful of the next seven generations*.

1. Introduction

Health telematics (also commonly referred to as telemedicine or telehealth, although there are useful distinctions to be made among the three concepts) refers to a technological discipline that has as its focus those health-related activities that require information and communication technologies (ICT) to transmit information across significant physical distance. By referring to ICT, this definition deliberately excludes such practices as the warning of disease outbreaks by means of shouting, beating drums, sending letters, or waving flags. The use of the telegraph, radio, and telephone to communicate health-related information would thus be the first meaningful applications of health telematics.

It should also be stressed that health telematics does not in and of itself necessitate the physical movement of material, financial, or human resources, whether medicine, hard-copy printed information, or any other substance encountered in health care. Health telematics deals only with the transmission of health-related information across substantial distance.

Health telematics is one of the newest and most powerful weapons in the high technology arsenal available to society in the struggle to secure better health status for its citizens. Like many advanced technologies, however, health telematics solutions must be carefully designed and implemented if significant and lasting health benefits are to be realized. This article attempts to define and describe health telematics, both as a component of health-care systems, and as a potent tool for societal change in the twenty-first century.

2. Background

2.1. ABC of Basic Telematics

Several further basic definitions are useful when trying to make sense of telematics as a technological innovation. The main constraints that govern how telematics can deal most effectively with data transmission can be listed as a short ABC of digital telecommunications. **A**nalog versus digital signals, **B**its and bytes as the components of digital data, **C**apacity or bandwidth of transmission media needed to transmit bytes of data, **D**ata compression to reduce bandwidth requirements, and **E**nhancement of digital data to yield additional information.

Analog versus digital signals: Analog signals are those that vary continuously: for instance, the indicator on a regular spring-operated weighing scale varies continuously, while that on a scale with a digital (e.g. LCD) display varies in fixed increments. Similarly, analog data when sent over a copper wire is defined by the continuously varying voltage (amplitude) in the signal. When an analog signal is digitized, the magnitude of the signal at specified (usually extremely small) intervals is determined as a binary number consisting of a string of 0s and 1s. A digital signal then consists of a *sequence of strings* of 0s and 1s. Although the signal is now "longer," the on/off nature of the signal components results in less noise and a much reduced error rate. Digital signals can be transmitted accurately much faster than can analog signals.

Bits and bytes: The origin and purpose of the commonly confused terms bits and bytes require clarification. The 0s and 1s of the binary computer (machine) language were referred to as binary digits, or “bits.” As it takes about eight bits of machine language to generate one alphanumeric character, the byte (defined as eight bits) has become the standard unit of measuring the size of data files. The kilobyte (1 kB = 1024 bytes), megabyte (1 MB = approx. 1000 kilobytes), gigabyte (1 GB = approx. 1000 megabytes), and terabyte (1 TB = approx. 1000 gigabytes) have now become commonplace in everyday speech. While image and data file size are always referred to in terms of bytes, the electronic transmission of data occurs purely in bits, that is in 0s and 1s; the speed of transmission media is therefore given in bits/second or bps.

Capacity and bandwidth: The capacity of a communication medium to carry data is measured in bps (see above), and is referred to as its *bandwidth*. A network using a variety of media is thus limited to the bandwidth of the link with the lowest (slowest) capacity. Effective videoconferencing and multimedia communications require wide bandwidth. The broader the bandwidth the higher the resolution of the images that can be transmitted in a reasonable period of time, and the less jerky the motion displayed on the receiving screen. The disadvantage of high bandwidth is its considerable cost. A lot of effective telemedicine can be carried out at relatively low bandwidth (e.g. over telephone lines and slow computer modems).

Data compression: Data compression is a process used to reduce the size of a file for purposes of saving storage space or reducing the time needed for its transmission. It works by describing the location of those file components that have the same binary value. A crude example will help to explain the process: In an X-ray image more than 8 MB in size there are in one part of the lung fields 68 contiguous pixels (picture elements) with the gray-scale value of 9 (i.e. 00001001). It will take far less space to “write” <the next 68 bytes have the value 9> than it does to write the following string of 0s and 1s: 00001001 . . . (528 more 0s and 1s) . . . 00001001.

If, in the above image, the eliminated data items (replaced by a reference to “the next 68 bytes”) each has the gray-scale value of exactly 9, then the image can be reconstituted exactly as it was before compression. This is referred to as loss-less compression, as the compression will not result in any loss of information. If, however, the 68 contiguous pixels ranged in gray-scale value between 8.9 and 9.1, then a compression that considers them all to be equal to 9 would be “lossy” compression. For some kinds of images this loss of information is unimportant, and for others it is unacceptable.

Lossy compression of medical images presents a major challenge to health telematics. There is evidence that certain levels of lossy compression, while reducing an image’s information content, will have no impact on a diagnostician’s ability to interpret the image. This is so primarily because the eye is unable to perceive the slight loss in information. Essentially loss-less compression of 23:1 is possible, depending on the amount of gray-scale redundancy in the original image. Data compression of files can be done using widely available software.

An image containing many data strings that have been abbreviated with or without information loss is referred to as a compressed image and will be much smaller in size than the original, uncompressed, image. The resulting reductions in transmission time and costs are very significant.

Enhancement and windowing: Once an image is in digital form, rendered into discrete picture elements (pixels) each with its own binary value, mathematical algorithms can be used for *enhancement or windowing*. Enhancement occurs when pixels with certain gray-scale values or ranges of values are assigned arbitrarily high or low values, so that the resulting pixels show up dramatically on the digital image. For instance, *edge enhancement* makes it possible to identify and highlight the locations where specific numeric discontinuities occur. Highlighting occurs by an arbitrary assignment of higher values to one side or the other of the discontinuity. The resulting information (i.e. the location of such a discontinuity in skeletal tissue) may, for instance, reveal the location of an otherwise invisible hairline fracture. This is useful because without enhancement the fracture (actually consisting of a sequence of adjacent pixels that have binary values significantly different from each other) may be too slight to be picked up by the human eye. In soft tissue, cancerous lesions can sometimes be identified by edge enhancement.
One disadvantage of manipulations like edge enhancement is that, besides making visible possible tissue anomalies, the resulting images will show many artifacts of enhancement, that is, apparent edges and discontinuities that do not indicate abnormal tissue. Such noise can create confusion and even lead to unnecessary interventions.

Windowing is another method used to make visible those tissue structures that, in analog images, are not readily apparent to the naked eye. In order to make sense of windowing, it will be necessary to reiterate briefly the nature of a monochrome (i.e. black and white) digital image. A digital image is an immense grid of pixels (similar to tiny squares like a chessboard), each of which has a gray-scale density determined by a (binary) numerical value. In an X-ray film image, for instance, these pixels will range from nearly opaque (non-dense muscle tissue) to nearly transparent (dense bone). The clear (white) and opaque (black) pixels are the extreme ends of the gray-scale gradient. If the gradient from white to black were subdivided into 10 contiguous tone blocks, the eye would easily be able see the border between the 10 blocks. However, this would not be the case if the same gradient were subdivided into 100 contiguous blocks, again ranging from clear at one end to black at the other—it would now appear as though the tones blended smoothly into each other as they progressed from white to black.

In other words, were an image to consist of only 10 shades of gray, all of its information contained in the image would be visible to the naked eye. On the other hand, an image that consists of 100 shades of gray will have pixels of “nearly the same” but not identical grayness, where the eye can no longer distinguish between them. If a lesion is actually a tiny fraction denser than the surrounding tissue, it is possible that the difference in gray-scale value may be too small for the naked eye to detect it. As diagnostic images can consist of between 250 and 1000 shades of gray, the detection of minute differences in gray-scale value becomes important.

Windowing renders these differences visible by allowing the selection of a small subset of gray-scale values (i.e. those that might “hide” a lesion) and arbitrarily setting the least dense of the selected values to white, and the most dense value to black. The result will be an image in which pixels still range from white to black, except that now the previously hidden lesion will be visible to the naked eye, its defining gray-scale values having been differentiated from the adjacent tissue's values by the expedient of changing *mathematically* the values of the respective pixel. Those values, previously on either side of the selected gray-scale subset, will now be either completely white, or completely black, and the information contained therein will be unavailable in the windowed image. As windowing does not involve permanent alteration of the digital image, no information is actually lost.

As any gray-scale range can be targeted for windowing, there is the risk that a preoccupation with windowing could lead to an inefficient image-reading process. Providing those who read the images with a set of pre-windowed images can minimize this. The nature and number of the pre-windowed images will depend on the kind of radiographic examination involved.

2.2. Definition of Health Telematics

To understand health telematics, it helps first of all to consider the etymology of the terms and then to examine some of the definitions that have been used to indicate its role and function. Clearly, health telematics is the application of telematics in the pursuit of health. It is instructive, therefore, to examine the meaning of telematics.

The word "informatics" is usually taken to refer to all activities involving information (usually computer-based) technology; the French, for example, refer to computer science as *l'informatique*. Informatics includes the acquisition, manipulation, storage, and dissemination of information. The relatively meaningful, though never used, term "tele-informatics" would then refer to that subset of informatics that involves information being sent over a significant physical distance (*tele*, from the Greek word for "distance"). However, consistent with a modern, if deplorable, convention in American English to eschew long words, the stem of tele-informatics was cut out to yield the simpler, but less informative, word "telematics." This generic term is now used to refer to any and all aspects of informatics that involve the spanning, at some stage or other, of a significant physical distance. The application of telematics in the service of health thus becomes health telematics.

One World Health Organization (WHO) group has defined health telematics as a "composite term for health-related activities, services and systems, carried out over a distance by means of information and telecommunication technologies, for the purposes of global health promotion, disease control and health care, as well as education, management, and research for health." But this must not be seen as an attempt to advance a final definition, as a debate as to the correct word for this revolutionary development in global health development will neither advance our understanding of what needs to be done, nor can it ever be settled conclusively. As with many definitions, one must guard against Rumpelstiltskinism (i.e. knowledge of the "true" name of something confers on users an unjustified aura of greater understanding). To the extent that there exist comparable terms that have attained some degree of general acceptance, it is intended in the material provided here that all such terms be considered roughly interchangeable unless otherwise stated. We shall therefore use the term health telematics here as the most inclusive concept in this area. In English there is another perfectly acceptable and synonymous term—telehealth—which is commonly used in Canada and the United States, both countries having pioneered the development and application of health telematics. However, the difficulty encountered when attempting to translate telehealth into other languages spurred the search for a more universally deployable term. Health telematics (which in French has become *télématique pour le santé*) satisfied the criterion for more universal utility.

Another reason the term telehealth may be less than globally suitable is a growing opinion that telehealth is, strictly speaking, not very meaningful—as health itself, unlike medicine, is neither a practice, an activity, nor a service that can be done or delivered "over distance." As the current popularity of the term telehealth grew out of a resistance to allowing the medical profession (as implied in telemedicine, one of the two most important sub-categories of health telematics, the other being tele-education) to own the overall mission of health care. By omitting the -atics suffix, the term telehealth also fails to provide an etymological link to informatics (i.e. to the key role played by information technology in this innovative approach to health development). Given the general acceptance of the concept of health informatics as representing informatics in the service of health, and the somewhat narrower but unambiguous medical informatics as representing informatics to facilitate medical care, the term health telematics effectively conveys the idea of telematics in the service of health.

According to the WHO definition, health telematics subsumes as its most important sub-categories such fields of activity as telemedicine, tele-education, telematics for research, and telematics for management. In the following, the focus will be on telemedicine and tele-education as the two most critical components, either of which should be seen as broad enough to include aspects of management and research.

The purpose of modern health telematics was to facilitate medical diagnosis and treatment for patients in remote areas who did not have ready access to health-care providers. There was also a need for technologies with which to provide health-care providers in isolated areas access to the literature and health databases, and the ability to consult with specialists and other care providers in distant centers. The potential of health telematics to help in the provision of education for those in isolated or under-served areas was also recognized at an early stage.

Next, we will consider the background of health telematics in terms of its history and its role in, and importance for, global health development.

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Biographical Sketch

Professor G.W. Brauer, an associate professor in the School of Health Information Science, University of Victoria, Victoria, British Columbia, Canada, is a citizen of both Canada and Germany. He lectures on epidemiology, health informatics, and the societal impact of information technology. Following graduation in 1974 from the University of Victoria with a Bachelor of Arts First Class Honours, he attended the University of British Columbia (UBC), where he received an M.A. in medical anthropology in 1975. The award of a New Zealand Medical Research Council Graduate Research Fellowship led to his spending three years in the South Pacific working as part of an epidemiological research team based at the Wellington Clinical School of Medicine. On his return to Canada, he held various positions with the UBC Health Systems Division, the British Columbia Cancer Control Agency, and the British Columbia Ministry of Health. With by now extensive experience in epidemiology and health services research, he was invited in 1988 to join the University of Victoria as a member of the teaching faculty of the newly established School of Health Information Science.

Recent developments in electronic communication and surveillance technologies have caused him to become interested in their potential impact on educational and democratic processes, especially about the increasing ability and desire of commercial and bureaucratic interests to use such technologies to exert control over the minds and actions of students and citizens. His current research focuses on emancipatory education and on how it might counteract what may be a dangerous progression toward a commercial and/or bureaucratic form of totalitarianism. In addition to his professorial duties, he is presently completing a doctorate in educational leadership and policy at UBC.